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of

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for

FIXTURE FOR MANUFACTURING MAGNETS FOR A VOICE COIL MOTOR

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation in part of U.S. Patent Application No. 09/231,712, filed on January 15, 1999, entitled "SPECIALLY ORIENTED MATERIAL AND MAGNETIZATION OF PERMANENT MAGNETS", the contents of which are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a fixture for manufacturing magnets. More specifically, the present invention relates to a fixture and method for pressing and orientating magnets for voice coil actuator motors.

BACKGROUND

Disk drives are widely used in computers and data processing systems for storing information in digital form. Disk drives typically utilize one or more rotating, storage disks and a plurality of data transducers to interact with each storage disk. An E-block having a plurality of spaced apart actuator arms retains the data transducers proximate each storage disk. An actuator motor moves the E-block and the data transducers relative to the storage disks.

The need to rapidly access information has led to disk drives having storage disks which are rotated at ever increasing speeds and an actuator motor which moves the E-block at ever increasing rates. Unfortunately, this typically results in increased heat, noise and power consumption of the disk drive.

Figure 1A illustrates a rear perspective view of a portion of a prior art, rotary, voice coil actuator motor 10P. In this embodiment, a flat, trapezoidal shaped coil 12P is positioned between two permanent magnets 14P and two flux return plates 16P. The coil 12P is secured to the E-block (not shown in Figure 1A). Current passing through the coil 12P causes the coil 12P to move relative to the permanent magnets 14P to move the E-block.

One factor which effects efficiency of the actuator motor 10P is the strength of the magnets 14P. In the prior art actuator motor 10P illustrated in Figure 1A, the magnets 14P include magnetization lines 18P (illustrated as arrows) which are oriented substantially perpendicular to the coil 12P. In this embodiment, the magnets 14P are made of a magnetic powder which is also oriented substantially perpendicular to the coil 12P.

Figure 1B illustrates a cross-sectional view of a prior art fixture 22P which can be used to manufacture the magnet 14P. The prior art fixture 22P includes a fixture body 24P, an upper punch 26P, and a lower punch 28P. This fixture body 24P defines a cavity for receiving magnet powder to form the magnet 14P. An orientating coil 30P creates a magnet field 32P having flux lines which orient the magnet powder in the magnet 14P.

Unfortunately, the strength of the magnets 14P illustrated in Figure 1A vary approximately 14-20 percent across the stroke of the coil 12P. More specifically, the strength of the magnets 14P is high, near the center and drops near the sides of the magnets 14P. This non-linearity causes difficulty in precisely moving the coil 12P. Inaccurate positioning of the coil 12P leads to data transfer errors between the data transducers and the storage disks.

In light of the above, it is an object of the present invention to provide an improved magnet and a fixture for making the improved magnet. It is another object to provide a fixture for manufacturing a magnet which is relatively easy to use. Yet another object is to provide a method for manufacturing a magnet which significantly improves the strength and performance of the magnet.

SUMMARY

A manufacturing fixture which satisfies these needs is provided herein. The manufacturing fixture is useful for manufacturing a magnet from a magnet powder for a motor. The manufacturing fixture includes a fixture body and an orientating device. The fixture body includes a fixture cavity for

receiving the magnetic powder. The orientating device aligns the magnetic powder in the fixture cavity.

The fixture cavity includes a cavity axis, a first cavity segment, second cavity segment, and a cavity transition between the first cavity segment and the second cavity segment. Uniquely, the orientating device creates a magnetic field having flux lines which extend (1) substantially transverse to the cavity axis near the cavity transition, (2) highly angled relative to the cavity axis near a perimeter of the fixture cavity and, (3) substantially parallel to the cavity axis intermediate the perimeter and the cavity transition.

The flux lines orient the magnet powder into a unique powder pattern which includes first region powder lines in a first region of the magnet which are substantially parallel with a first region axis and second region powder lines in a second region of the magnet which are angled relative to the first region axis.

This powder pattern subsequently facilitates a unique magnetization pattern in the magnet. This magnetization pattern results in higher magnetic flux densities throughout the magnet, higher magnetic flux densities at the parts of the magnet which interact with a coil of the motor, and higher average magnetic flux densities in the magnet.

Additionally, the higher magnetic flux densities at the sides of the magnet body, i.e. a greater radius, results in higher torques on the coil of the motor. This enables the magnet to generate more force from a given amount of current in the coil and increases the efficiency of the motor. This also reduces the amount of power consumed by the motor, reduces the amount of heat and noise generated by the motor during operation and increases operational time of the motor for a given battery charge. Further, the size of the magnet can be reduced for a given force requirement. These considerations are particularly important for computer disk drives, which often operate in heat and noise sensitive environments, or on battery power.

The present invention is also a method for manufacturing a magnet. The method includes the steps of positioning a magnet powder in the fixture cavity of the manufacturing fixture and aligning a portion of the magnet

powder in the fixture cavity with a magnetic field to form the powder pattern outlined above. The method can also include the step of magnetizing the magnet to include the magnetization pattern outlined above.

Importantly, the manufacturing fixture is used to make a magnet having a unique powder pattern. This powder pattern allows the magnet to accept a unique magnetization pattern which increases the amount of force generated for a given amount of current in the coil. This increases the efficiency, accuracy and performance of the actuator motor, thereby reducing data seek times and amount of power consumed by the actuator motor.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

Figure 1A is a perspective view of a portion of a prior art actuator motor;

Figure 1B is a cross-sectional view of a prior art fixture;

Figure 2 is a perspective view of a disk drive having features of the present invention;

Figure 3 is an exploded perspective view of a portion of an actuator motor having features of the present invention;

Figure 4 is a top perspective view of a portion of a magnet including a powder pattern having features of the present invention;

Figure 5 is a front plan view of a lower magnet illustrating a portion of the powder pattern on the inner side;

Figure 6 is a rear plan view of the lower magnet of Figure 5 illustrating a portion of the powder pattern on the outer side;

Figure 7 is a side plan view of the lower magnet of Figure 5 illustrating a portion of the powder pattern on a radial side;

Figure 8 is a view of the powder pattern as seen from Line 8-8 of Figure 3;

Figure 9 is a view of the powder pattern as seen from Line 9-9 of Figure 3;

Figure 10A is a front plan view of a first embodiment of a portion of an actuator motor, without coil, illustrating a portion of a magnetization pattern;

Figure 10B is a front plan view of a second embodiment of a portion of an actuator motor, without coil, illustrating a portion of a magnetization pattern;

Figure 11 is a top perspective view of a pair of magnets, illustrating a portion of the magnetization pattern;

Figure 12 is a top perspective view of a single magnet illustrating a portion of the magnetization pattern;

Figure 13 is a side perspective view of the magnet of Figure 12;

Figure 14 is a front plan view of a magnet illustrating a portion of the magnetization pattern on the inner side;

Figure 15 is a rear plan view of the magnet of Figure 14 illustrating a portion of the magnetization pattern on the outer side;

Figure 16 is a side plan view of the magnet of Figure 14 illustrating a portion of the magnetization pattern on a radial side;

Figure 17 is a view of the magnetization pattern as seen from Line 8-8 Figure 3;

Figure 18 is a view of the magnetization pattern as seen from Line 9-9 of Figure 3;

Figure 19 is a side plan illustration of a manufacturing fixture having features of the present invention;

Figure 20A is a top perspective illustration of the shape of the fixture cavity, including a plurality of curves which illustrate the orientation of the flux lines, the orientation of the powder pattern, and the orientation of the magnetization pattern;

Figure 20B is a top perspective illustration of a magnet including a plurality of curves which illustrate the orientation of the powder pattern;

Figure 20C is a top perspective illustration of a magnet including a plurality of curves which illustrate the orientation of the magnetization pattern;

Figure 21 is a cross-sectional view of the orientating device taken on lines 21-21 of Figure 19;

Figure 22 is an alternate cross-sectional view of the orientating device;

Figure 23 is an illustration of a magnet and an actuator;

Figure 24 is an illustration of an orientating device above a magnet;

Figure 25 is a side plan illustration of a magnetization fixture and magnet body having features of the present invention; and

Figure 26 is a graph which illustrates the performance characteristics of various magnets.

DESCRIPTION

The present invention is directed to a manufacturing fixture 11 (illustrated in Figure 19) for manufacturing magnets 24. As provided below, magnets 24 produced by the manufacturing fixture 11 have improved performance characteristics including higher average magnetic flux densities across the magnet 24.

The manufacturing fixture 11 is particularly useful for manufacturing magnets 24 for an actuator motor 20 for a disk drive 10. Alternately, the manufacturing fixture 11 and process described herein can be used to make magnets for other types of motors.

Figure 2 illustrates a disk drive 10 having a disk housing 12, a disk assembly 14, transducer assemblies 16, an E-block 18 and the actuator motor 20. Referring to Figure 3, the actuator motor 20 includes an actuator coil 22, one or more permanent magnets 24, and one or more flux return plates 25.

As an overview, the manufacturing fixture 11 allows each magnet 24 to accept a magnetization pattern 26 (illustrated in Figures 10-18) which increases the amount of force generated by each magnet 24 on the actuator coil 22 of the actuator motor 20 from a given amount of current in the actuator

coil 22. This allows the actuator motor 20 to quickly move the E-block 18 and the transducer assemblies 16 to decrease the data recovery time. Further, the increased efficiency of the actuator motor 20 reduces energy consumption and increases operational time of the actuator motor 20 for a given battery charge for a portable unit. Moreover, the magnets 24 can be used with thinner flux return plates 25.

A detailed description of the various components of a disk drive 10 is provided in U.S. Patent No. 5,208,712, issued to Hatch et al, and assigned to Quantum Corporation, the Assignee of the present invention. The contents of U.S. Patent No. 5,208,712, are incorporated herein by reference. Accordingly, this discussion is limited to the aspects of the disk drive 10 which particularly relevant.

The drive housing 12 retains the various components of the disk drive 10. The drive housing 12 is formed with a cover (not shown), a base 28 and spaced apart side walls 30. The disk assembly 14 includes one or more storage disks 32 mounted to a spindle hub 34. A spindle motor (not shown) rotates the spindle hub 34 and the storage disks 32 at a constant angular velocity.

The E-block 18 includes a tubular actuator hub 36 and one or more actuator arms 38 which cantilever away from the actuator hub 36. The actuator hub 36 rotates on an actuator shaft 40 which is secured to the base 28. The actuator arms 38 rotate with the actuator hub 36 and position the transducer assemblies 16 between the disks 32. The number and spacing of the actuator arms 38 varies according to the number and spacing of the disks 32.

The transducer assembly 16 typically includes a load beam 42 used to attach each data transducer 44 to one of the actuator arms 38. Typically, one data transducer 44 interacts with a single storage surface on one of the storage disks 32 to access or transfer information to the storage disk 32.

The actuator motor 20 precisely moves the E-block 18 and the transducer assembly 16 relative to the storage disks 32. In the embodiment shown in the Figures, the actuator motor 20 is a rotary voice coil actuator. In

this embodiment, the flat, trapezoidal shaped actuator coil 22 is attached to the actuator hub 36. The actuator coil 22 is disposed between two permanent magnets 24 and the flux return plates 25. The actuator coil 22 is separated from the permanent magnets 24 by an air gap. The flux return plates 25 serve as a return path for magnetic fields from the magnet 24 and may be formed of soft iron or steel. Current passing through the actuator coil 22 causes the actuator coil 22 to move relative to the magnets 24. This causes the actuator hub 36 and the actuator arms 38 to rotate. In an alternate embodiment, the actuator motor 20 could be a linear actuator motor (not shown) which moves radially with respect to the disks 32.

Figure 3, illustrates an exploded view of an actuator motor 20 which utilizes two magnets 24. More specifically, one of the magnets 24 in this embodiment is positioned above the actuator coil 22 and one of the magnets 24 is positioned below the actuator coil 22. Alternately, the actuator motor 20 could include a single magnet positioned either above or below the actuator coil 22. Each magnet 24 is defined by a curved or substantially arched shaped magnet body 46 which is made of a magnet powder 48 (shown in Figures 4-9). The magnet body 46 is defined by a substantially flat top surface 50, a spaced apart, substantially flat bottom surface 52, an arc shaped inner side 54, an arc shaped outer side 56, and a pair of spaced apart radial sides 58. A transition zone 60 vertically divides the magnet body 46 into a first segment 62 and a second segment 64 which are side-by-side. The transition zone 60 is represented by dashed lines. Each of the segments 62, 64, when magnetized, has a north pole 66 and a south pole 68. The poles 66, 68, of the first and second segments 62, 64, are inverted.

In the embodiment illustrated in the Figures, the magnet body 46 is a unitary structure. Alternately, the first and second segments 62, 64 can be distinct structures which are made independently and subsequently positioned side-by-side to form the magnet body 46.

Each segment 62, 64, includes a first region 70 (represented by dashed lines in Figures 3, 8, 9, 17, and 18) having a first region axis 72 which extends between the north pole 66 and the south pole 68 and a second

region 74 which encircles and surrounds the first region 70. The first region 70 illustrated in the Figures 3, 8, 9, 17, and 18 is shaped somewhat similarly to a circular cylinder and has a circular cross-section. The second region 74 is arched shaped and is defined by a portion of the top surface 50, a portion of the bottom surface 52, a portion of the inner side 54, a portion of the outer side 56, one of the radial sides 58 and the transition zone 60. Basically, second region 74 is defined by the perimeter of each segment 62, 64. The size and shape of the first region 70 and the second region 72 can be varied according to the design requirements of the magnet 24.

Importantly, the magnet body 46 is manufactured utilizing the manufacturing fixture 11 which enhances the ability of the magnet body 46 to retain the unique magnetization pattern 26. The manufacturing process includes aligning and orientating the magnet powder 48 during manufacturing to form a unique powder pattern 75 with the manufacturing fixture 11. A representative portion of one embodiment of the resulting powder pattern 75 is illustrated in Figures 4-9. The magnet powder 48 is aligned into the unique powder pattern 75 to enhance ability of the magnet body 46 to retain the magnetization pattern 26. The alignment of the magnet powder 48 in the magnet body 46 is designed to correspond to the desired magnetization pattern 26.

The term powder pattern 75 as used herein shall mean the pattern which is formed by the oriented and aligned magnet powder 48 in the magnet 24. The powder pattern 75 is only visible at a microscopic level. The magnet powder 48 is illustrated in Figures 4-9 to facilitate understanding of the present invention. More specifically, Figure 4 illustrates the powder pattern 75 from a perspective view, Figure 5 illustrates the powder pattern 75 when looking towards the inner side 54 of the magnet body 24, Figure 6 illustrates the powder pattern 75 when looking towards the outer side 56, Figure 7 illustrates the powder pattern 75 when looking a radial side 58, Figure 8 illustrates the powder pattern 75 as seen from Line 8-8 of Figure 3 and Figure 9 illustrates the powder pattern 75 as seen from Line 9-9 of Figure 3.

The powder pattern 75 for each segment 62, 64, includes first region powder lines 76 (illustrated in Figures 8 and 9) in the first region 70 and second region powder lines 78 in the second region 74. The first region powder lines 76 are substantially parallel with the first region axis 72 while the second region powder lines 78 are angled relative to the first region axis 72. Thus, the powder pattern 75 is defined by substantially vertical first region powder lines 76 in the first region 70 and angled second region powder lines 78 in the second region 74.

Referring to Figures 8-9, the first region powder lines 76 near the second region 74 are still substantially parallel to the first region axis 72. It should be recognized, however, that the first region powder lines 76 tend to angle slightly relative to the first region axis 72 as the radial distance from the first region axis 72 increases. Further, the angle of the second region powder lines 78 increases as the radial distance from the first region axis 72 increases. Stated another way, the second region powder lines 78 near the first region 70 are almost parallel with the first region axis 72 while the second region powder lines 78 near the sides 54, 56, 58, are more angled. In particular, the second region powder lines 78 near the sides 54, 56, 58 can be angled between approximately 20 and 90 degrees relative to the first region axis 72.

Preferably, the second region powder lines 78 throughout the entire second region 74 are angled relative to the first region axis 72. More specifically, the second region powder lines 78 for each second region 74 are angled relative to the first region axis 72 near the inner side 54, the outer side 56, the radial side 58 and the transition zone 60. The second region powder lines 78 near the sides 54, 56, 58 and the transition zone 60 are substantially perpendicular or transverse to the first region axis 72.

It should be noted that in the first segment 62, when moving from the bottom surface 52 to the top surface 50, the second region powder lines 78 are angled towards the first region axis 72. Alternately, in the second segment 64, when moving from the bottom surface 52 to the top surface 50,

the second region powder lines 78 are angled away from the first region axis 72.

To increase the efficiency of the actuator motor 20, the magnet body 46 is preferably magnetized to have the magnetization pattern 26 illustrated in Figures 10-18. As way of background, Figure 10A illustrates a portion of an actuator motor 20 and the magnetization pattern 26 in a couple of magnets 24 used in the actuator motor 20, Figure 10B illustrates another embodiment of an actuator motor 20 and the magnetization pattern 26 in a single magnet 24 used in the actuator motor 20, Figure 11 is a top perspective view of a pair of magnets 24 illustrating the magnetization pattern 26, Figure 12 is a top perspective view of a single magnet 24, Figure 13 is a side perspective view of the magnet 24, Figure 14 illustrates the magnetization pattern 26 when looking towards the inner side 54 of the magnet body 24, Figure 15 illustrates the magnetization pattern 26 when looking towards the outer side 56, Figure 16 illustrates the magnetization pattern 26 when looking a radial side 58, Figure 17 illustrates the magnetization pattern 26 as seen from Line 8-8 of Figure 3 and Figure 18 illustrates the magnetization pattern 26 as seen from Line 9-9 of Figure 3.

Specifically, each segment 62, 64 of the magnet 24 includes a magnetization pattern 26 having (i) first region magnetization lines 94 (illustrated in Figures 17 and 18) in the first region 70 which are substantially parallel with the first region axis 72 and (ii) second region magnetization lines 96 in the second region 74 which are angled relative to the first region axis 72.

Referring to Figures 17 and 18, the first region magnetization lines 94 near the second region 74 are still generally parallel to the first region axis 72. It should be recognized, however, that the first region magnetization lines 94 tend to angle slightly relative to the first region axis 72 as the radial distance from the first region axis 72 increases. Similarly, a second region magnetization line 96 orientation gradient exists in the second region 74 as the radial distance away from the first region axis 74 increases. More specifically, for each second region 74, the second region magnetization lines

92 near the first region 70 are almost parallel with the first region axis 72 while the second region magnetization lines 92 away from the first region 70 are more angled. Stated another way, the second region magnetization lines 92 for each second region 74 transfer from being almost vertical near the first region 70 to severely angled away from the first region 70. The angle of the second region magnetization lines 92 increases as the distance from the first region axis 72 increases. In particular, the second region magnetization lines 92 near the sides 54, 56, 58 and the transition zone 60 can be between approximately 20 and 90 degrees relative to the first region axis 72. Typically, the second region magnetization lines 92 near the transition zone 60 are perpendicular to the first region axis 72.

Preferably, the second region magnetization lines 92 throughout the entire second region 74 are angled relative to the first region axis 72. More specifically, the second region magnetization lines 92 for each second region 74 are angled relative to the first region axis 72 near the inner side 54, the outer side 56, each radial side 58 and the transition zone 60.

As discussed above, the magnet powder 48 is aligned into the powder pattern 75 to enhance the ability of the magnet body 46 to retain the magnetization pattern 26. A comparison of Figures 5-9 illustrates that the alignment of magnet powder 48 in the powder pattern 75 is somewhat similar to the alignment of the magnetization pattern 26 illustrated in Figures 14-18. As provided herein, the alignment of the magnet powder 48 in the magnet body 46 is designed to correspond to alignment of the magnetization lines 94, 96 in the magnetization pattern 26.

The magnet powder 48 is preferably formed into the magnet body 46 in the manufacturing fixture 11 utilizing powder metallurgy processes. Referring to Figure 19, the manufacturing fixture 11 includes a fixture body 100 which defines a fixture cavity 102, an upper punch 104, a lower punch 106 and an orientating device 108. The upper punch 104 and lower punch 106 are movable relative to each other to compress the magnet power 48 (not shown in Figure 19) in the fixture cavity 102, while the orientating device 108 orientates the magnetic powder 48. In the embodiment illustrated, the fixture

cavity 102 is arched or curved shaped. In a typical powder metallurgy process, the magnet powder 48 (not shown in Figure 19) is initially added to the fixture cavity 102. Subsequently, the magnet powder 48 is compressed in the fixture cavity 102 with the upper punch 104 and lower punch 106 to form a pressed magnet body 46 (not shown in Figure 19). Next, the magnet body 46 is removed from the fixture cavity 102 and heated.

Importantly, during pressing of the magnet powder 48, the magnet powder 48 is orientated into the powder pattern 75 with the orientating device 108. More specifically, the orientating device 108 generates a magnetic field having flux lines 110 which extend across the fixture cavity 102 to create the powder pattern 75. The flux lines 110 provided in Figure 19 are merely an example of the thousands of flux lines which extend across the fixture cavity 102. Typically, the flux lines 110 are used to orient the magnet powder 48 prior to and during the compression of the magnet powder 48 in the fixture cavity 102.

Figure 20A provides a perspective illustration of the shape of one embodiment of the fixture cavity 102. It should be recognized that the fixture cavity 102 illustrated is shaped substantially similar to one magnet 24. However, the fixture cavity 102 is slightly larger than the magnet 24 to account for shrinkage during manufacturing. Alternately, for example, the fixture cavity 102 could be shaped substantially similar to one of the segments 62, 64 of the magnet 24.

The fixture cavity 102 includes a first cavity segment 112, a second cavity segment 114, a cavity transition 116, and a pair of cavity axes 118 which extend through each cavity segment 112, 114. The fixture cavity 102 is bounded by an upper side 120, a lower side 122 and a cavity perimeter 126. The first cavity segment 112 and the second cavity segment 114 are side by side and are separated by the cavity transition 116. Each cavity axis 118 is substantially parallel with the first region axis 72. Further, each cavity axis 118 illustrated in the Figures is substantially vertical and perpendicular to the sides 120, 122.

Figure 20A includes a plurality of curves designated 126 a-l which illustrate the approximate angle of the flux lines 110 (not shown in Figure 20A) in the fixture cavity 102 relative to each cavity axis 118. More specifically, each curve 126 a-l in each cavity segment 112, 114 represents an approximate area in the fixture cavity 102 in which the angle of the flux lines 110 relative to each cavity axis 118 is approximately the same. For example, curves 126a represent the area in the fixture cavity 102 in which the flux lines 110 are at an approximately 5 degree angle relative to each cavity axis 118. Curves 126b represent the area in the fixture cavity 102 in which the flux lines 110 are at an approximately 15 degree angle relative to each cavity axis 118. Curves 126c represent the area in the fixture cavity 102 where the flux lines 110 are approximately at a 25 degree angle relative to each cavity axis 118. Curves 126d represent an approximate area where the flux lines 110 are approximately at a 35 degree angle relative to each cavity axis 118. Curves 126e represent an approximate area where the flux lines 110 are approximately at a 45 degree angle relative to each cavity axis 118. Curves 126f represent an approximate area in which the flux lines 110 are approximately at a 55 degree angle relative to each cavity axis 118. Curves 126g represent an approximate area where the flux lines 110 are approximately at a 65 degree angle relative to each cavity axis 118. Curves 126h represents an approximate area where the flux lines 110 are approximately at a 75 degree angle relative to each cavity axis 118. Curves 126i represent an approximate area where the flux lines 110 are approximately at an 85 degree angle relative to each cavity axis 118.

As illustrated by the curves 126 a-l in Figure 20A, the flux lines 110 extend almost transverse to each cavity axis 118 at the perimeter 124 and the cavity transition 116 and almost parallel to the cavity axis 118 intermediate the cavity perimeter 124 and the cavity transition 116. The example provided in Figure 20A is merely exemplary of a pattern of flux lines which can be used with the present invention.

It should be noted that alignment of the flux lines 110, the alignment of magnet powder 48 in the powder pattern 75 and the alignment of the

magnetization pattern 26 are preferably substantially the same, accounting for changes which occur during manufacturing, such as sintering, pressing and grinding. More specifically, to make the powder pattern 75 illustrated in Figures 5-9, the flux lines 110 would extend through the fixture cavity 102 in a somewhat similar fashion. Thus, the alignment of the flux lines 110 in the fixture cavity 102 is designed to correspond to the alignment of the magnet powder 48 in the magnet body 46 and the alignment of the magnetization lines 94, 96 in the magnetization pattern 26.

Figure 20B illustrates a perspective view of a magnet 24 having a plurality of curves designated 226 a-l which illustrate the shape of a power pattern 75 which is made by the fixture 11. More specifically, curves 226a-l illustrate the angle of the powder lines 76, 78 in the magnet 24 relative to the first region axis 72. For example, curves 226a represent the area in the magnet 24 in which the powder lines 76, 78 are approximately at a 5 degree angle relative to each first region axis 72. Similarly curves 226b represent the area in the magnet 24 in which the powder lines 76, 78 are approximately at a 15 degree angle relative to each first region axis 72. Curves 226c represent an area where the magnetization lines 94, 96 are at a 25 degree angle relative to each first region axis 72. Curves 226d represent an approximate area where the powder lines 76, 78 are approximately at a 35 degree relative to each first region axis 72. Curves 120e represent an approximate area where the powder lines 76, 78 are approximately at a 45 degree angle relative to each first region axis 72. Curves 226f represent an approximate area in which the powder lines 76, 78 are approximately at a 55 degree angle relative to each first region axis 72. Curves 226g represent an approximate area where the powder lines 76, 78 are approximately at a 65 degree angle relative to each first region axis 72. Curves 226h represent an area where the powder lines 76, 78 are approximately at a 75 degree angle relative to each first region axis 72. Curves 226i represent an area where the powder lines 76, 78 are approximately at an 85 degree angle relative to each first region axis 72.

Somewhat similarly, Figure 20C illustrates a perspective view of a magnet 24 having a plurality of curves designated 326 a-l which illustrate the shape of the magnetization pattern 26. More specifically, curves 326a-l illustrate the angle of the magnetization lines 94, 96 in the magnet 24 relative to the first region axis 72. For example, curves 326a represent the area in the magnet 24 in which the magnetization lines 94, 96 are approximately at a 5 degree angle relative to each first region axis 72. Similarly curves 326b represent the area in the magnet 24 in which the magnetization lines 94, 96 are approximately at a 15 degree angle relative to each first region axis 72. Curves 326c represent an area where the magnetization lines 94, 96 are at a 25 degree angle relative to each first region axis 72. Curves 326d represent an approximate area where the magnetization lines 94, 96 are approximately at a 35 degree relative to each first region axis 72. Curves 326e represent an approximate area where the magnetization lines 94, 96 are approximately at a 45 degree angle relative to each first region axis 72. Curves 326f represent an approximate area in which the magnetization lines 94, 96 are approximately at a 55 degree angle relative to each first region axis 72. Curves 326g represent an approximate area where the magnetization lines 94, 96 are approximately at a 65 degree angle relative to each first region axis 72. Curves 326h represent an area where the magnetization lines 94, 96 are approximately at a 75 degree angle relative to each first region axis 72. Curves 326i represent an area where the magnetization lines 94, 96 are approximately at an 85 degree angle relative to each first region axis 72.

Figures 21 and 22 each illustrate a separate embodiment of an orientating device 108 which can be used to generate the flux lines 110. In the embodiments illustrated in Figures 21 and 22, the orientating device 108 includes a housing 128 and a pair of spaced apart, adjacent orientating coils 130. In the embodiment illustrated, the orienting device 108 is positioned between the upper punch 104 and the upper side 12 of the fixture cavity 102. Further, the housing 128 is shaped somewhat similar to the magnet 24 and is rectangular, arch shaped.

Current 132 passing through the orientating coils 130 creates the flux lines 110 which orientate the magnet power 48. Thus, the shape of the orientating coils 130 varies according to the desired pattern of the flux lines 110. In the embodiments illustrated in Figures 21 and 22, each orientating coil 130 is shaped similar to a rectangular tube. Each orientating coil 130 can be made by creating a rectangular shaped channel 132 in the housing 128. Subsequently, one or more loops of conductive wire (not shown) and epoxy (not shown) can be wrapped within the channels 132 to form the orientating coils 130. The orientating coils 130, for example, can be arranged as either an interconnected pair of coils 130 (Figure 21) or dual, independent coils 130 (Figure 22). The two orientating coils 130 can be connected in series, as illustrated in Figure 21, or in parallel, as illustrated in Figure 22.

Preferably, the geometry of the orientating coils 130, and alignment of the flux lines 110, the alignment of the powder pattern 75, and the alignment of the magnetization pattern 26 are designed to have a particular geometric relationship to the geometry and movement of the actuator coil 22 in the actuator motor 20. Stated another way, the geometry of the orientating coils 130 is preferably related to the geometry and movement of the actuator coil 22. Moreover, the geometry of the orientating coils 130 and the resulting flux lines 110 can be altered to reflect the desired stroke of the actuator coil 22. This allows the designer of the actuator motor 20 to optimize the design of the magnet 24 for a given actuator coil 22 and a desired stroke of the actuator coil 22.

The relationship between the geometry of the orientating coils 130 and the actuator coil 22 (not shown in Figures 23 and 24) can be better understood with reference to Figures 23 and 24. In particular, Figure 23 illustrates a magnet 24 and a pair of dummy coils 136 a,b. Each dummy coil 136a,b is shaped similar to the desired design of the actuator coil 22 (not shown in Figures 23 and 24). One of the dummy coils 136 a,b is positioned to reflect the ends of the desired stroke. For an actuator motor 20 (not shown in Figures 23 and 24) designed for use through its entire range, one of the dummy coils 136a,b is positioned near each of the sides 58 of the magnet 24.

More specifically, each dummy coil 136a, 136b is placed at each extreme movement position relative to the magnet 24 of the actuator coil 22. Next, an imaginary current 138 is directed through each dummy coil 136a, 136b in a different direction. Subsequently, overlapping regions 140 are eliminated in which the imaginary currents 138 would cancel. The geometry of the orientating coils 130 should be similar as possible to the remaining current carrying regions in the dummy coils 136a,b. Figure 24 illustrates the resulting design of the orientating coils 130 relative to the magnet 24.

The magnet body 46 is preferably made of anisotropic NdBFe which is a strong permanent magnet. However, those skilled in the art will recognize that other materials can be utilized. For example, the unique process for manufacturing the magnet 24 allows for the use of less expensive materials, such as Samarium Cobalt or Ceramic Ferrite.

Referring to Figure 25, the magnet body 46 can be subjected to the magnetization pattern 26 utilizing an impulse magnetizing process with a magnetizing fixture 98. The manufacturing of the appropriate magnetizing fixture 98 for magnetization of magnet body 46 may be accomplished using upper and lower magnetizing conductors, and/or shaped steel magnetizing yokes (not shown).

Figure 26 illustrates comparison of the performance of three alternate magnets. In particular, curve designated 140 illustrates the performance of a prior art actuator motor 10P with the magnets 14P having parallel magnetization lines 18P as illustrated in Figure 1A and the thickness of the flux return plates 16P and the magnets 14P optimized. Curve 142 illustrates the performance of an actuator motor 20 using a pair of magnets 24 made in accordance with the present invention. It should be noted that an approximately 11% increase in performance is realized over the prior art optimized actuator motor 10P. Finally, curve 144 illustrates the performance of actuator motor 20 having a pair of magnets 24 made in accordance with the present invention with the thickness of the magnets 24 and the flux return plates 25 reoptimized. It should be noted that an approximately 25% increase in performance is realized over the prior art optimized actuator motor 10P.

The distinguishing characteristic of the magnet 10 built in accordance with the present invention is the magnet powder 46 is aligned during manufacturing to have a powder pattern 75 which corresponds to the magnetization lines 94, 96 in the magnetization pattern 26.

Importantly, each magnet 24 is made utilizing a unique manufacturing process and the magnet 24 includes a unique magnetization pattern 26. The magnetization pattern 26 results in higher magnetic flux densities at the sides 54, 56, 58 of the magnet 24, higher average magnetic flux densities. The higher magnetic flux densities create higher seek forces for quicker data seek times.

Additionally, the higher magnetic flux densities at the sides 54, 56, 58 of the magnet body 46 , i.e. a greater radius, results in higher torques on the actuator coil 22 of the actuator motor 20. This enables the magnet 24 to generate more force from a given amount of current in the coil 22 and increases the efficiency of the actuator motor 20. This also reduces the amount of power consumed by the actuator motor 20, reduces the amount of heat and noise generated by the actuator motor 20 during operation and increases operational time of the actuator motor 20 for a given battery charge. Further, the size of the magnet 24 can be reduced for a given force requirement. These considerations are particularly important for computer disk drives 10, which often operate in heat and noise sensitive environments, or on battery power.

While the particular manufacturing fixture 11 as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.